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Physiologically Patterned Weak Magnetic Fields Applied Over Left Frontal Lobe Increase Acceptance of False Statements as True

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Fifty men and women were exposed to only one of four experimentally generated magnetic fields over the left prefrontal region (above the eyebrow) or to a sham field immediately after the words "true" or "false" were presented following statements of definitions of words for a "foreign language". Three of the patterns (25 Hz, 50 Hz, or burst-firing) with intensities between 1 and 10 microT were presented for 1 s during the refutation process (immediately after the offset of "true" or "false") for specific statements from a total of 28 statements. The fourth pattern was a variable approximately 7–10 Hz (10 nT) field generated from the circuitry that was present continuously during the entire experiment. When the statements were presented again, the groups who had received the burst-firing ("limbic") or 25 Hz pulsed magnetic fields during the refutation process accepted about twice the number of false statements as true compared to those exposed to the 50 Hz field or sham-field conditions. The treatments did not significantly affect the numbers of true statements accepted as false. These results suggest that the appropriately pulsed magnetic field during the refutation process of what one has been told or has heard can increase the probability a person will accept a false statement as true.

Keywords Decisions; Magnetic fields; Thought control; Cognition.

Introduction

The decision of truth was argued by Spinoza, the sagacious 17th century philosopher, to require a refutation process. The first stages of cognitive processing required the acceptance of all information as "true". This was followed by either accepting or rejecting this assumption. Gilbert et al. (1990) found that if the refutation process was disrupted by a tone, a false statement could later be accepted as true. We designed an experiment to test the hypothesis that weak complex magnetic fields pulsed over the left prefrontal region (because of its involvement in syntactic reasoning) at the moment of accepting or refuting a statement could increase the likelihood of later accepting a false statement as true.

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Gilbert et al. (1990) transformed the Spinozian assumptions into an experiment by presenting a series of propositions on a computer screen each of which contained a noun that was allegedly from the ''Hopi language'' and its English equivalent. There were a total of 28 definitions. Each statement was followed by the word true, false, or a blank screen. On four pre-selected trials the subjects were interrupted by being required to push a button to the sound of a tone. At the end of the presentation of propositions, the subjects were given the items again and were asked, one proposition at a time, if it was true or false. Subjects accepted more false propositions as true if they had been disrupted by the tone during the refutation process.

We employed four specific electromagnetic patterns as substitutes for the disruptive tone of Gilbert et al. (1990) on the bases of theoretical and empirical evidence. They were 25 Hz, 50 Hz, and a burst-firing pattern (Martin et al., 2004a,b). We reasoned that amplitude modulations every 25 ms (50 Hz) to 50 ms (25 Hz) would be within the range that could affect the recursive transcerebral cohesive neurogenic magnetic fields associated with consciousness (Llinas and Ribary, 1993). During the early stages of the experiment we measured a variable 7–10 Hz very weak (about 10 nT) magnetic field being generated from the equipment to the solenoid that was applied over the skull. This group was included as the (post hoc) fourth treatment group. We selected the left prefrontal region of the subjects' brains as the focus because this region is involved with reflection, self-monitoring, and the experiences of ''voluntary'' control of both verbal and motor behaviors.

Method

Subjects

A total of 50 undergraduate students (25 men and 25 women, ages 18–30 years) enrolled in first-year psychology courses volunteered to be subjects. Each received a bonus mark that contributed to the final grade. There were 10 subjects per group.

Procedure

The magnetic fields were generated through a custom made DAC (digital-to-analog converter) that sent voltage variations from software (Complex 2) supported by a Zenith SupersPort 286 portable computer to a pair of solenoids (reed switches with parallel N–N and S–S poles to increase deflection of the field through the skull) contained with a film canister (3.5 cm wide, 5 cm long) that was held by velcro over the subjects' left prefrontal region just over the eyebrow.

Subjects were sequentially allocated over a period of two months to only one of the four conditions or to a sham field condition (solenoids disconnected from the DAC) so there was a total of 5 men and 5 women per condition. Each statement was presented on the computer screen 0.8 m in front of the subject for 8 s. This was followed by 6 s of blank screen and then by the presentation of a 3 s signal word of either ''true'', ''false'' or a blank screen.

Three of them were ''pulsed'' for only 1 s immediately after the disappearance of the signal word ''true'', ''false'', or blank screen. In other words, instead of pushing a button to the sound of a tone to imitate Gilbert's procedure, the subjects were simply exposed to one of the 1 s pulses without their awareness of which ''word'' was being stimulated or which pattern was being presented.

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The four temporal patterns were: (1) 25 Hz square waves (20 ms on, 20 ms off for 1 s); (2) 50 Hz square wave (10 ms on 10 ms off for 1 s); and (3) the burst-firing field developed by Richards et al. (1993) for 1 s. The fourth, which was a variable 7–10 Hz square wave generated from an electronic cricket (used as an intensity-to-frequency converter but generated a small field when no input was present) in the DAC when the computer-generated patterns were not operating, was present continuously for the entire experiment.

The point duration for each value between 0 and 255 that generated the patterns was 1 ms. This meant that the value 127 was 0 V, 255 was + 5 V, and the value 0 was −5 V. This specific value for each point that comprised the column of numbers that comprised the patterns occurred for 1 ms before the next voltage associated with the next number was activated. The strength of the fields adjacent to the skull from the first three fields ranged between 10 mG and 100 mG (1–10 microT). The field strength for the continuous ''background'' 7–10 Hz variable field generated through the DAC was about 10 nT.

Within 3 min after the pairing phase, the same 28 words were presented again for 5 s during which time the subject pressed a key to indicate if each proposition was ''true'' or ''false''. The numbers of false propositions accepted as true or false and the numbers of true propositions accepted as true or false (four combinations) were counted automatically by the software and calculated by the method of Gilbert et al. (1990). Statistical analyses were completed by SPSS software. The experimenter, the first author, knew which subjects were receiving which condition but was not familiar with the specifics of the hypothesis or the pattern configurations.

Results

Two way analysis of variance (5 treatments, 2 sexes) demonstrated statistically significant ($F(4,40) = 2.92$, $p < 0.05$; one-tailed test) treatment differences. The means and standard errors of the mean for the numbers of false statements accepted as true for groups exposed to one of the five treatment conditions during the refutation process are shown in Figure 1.

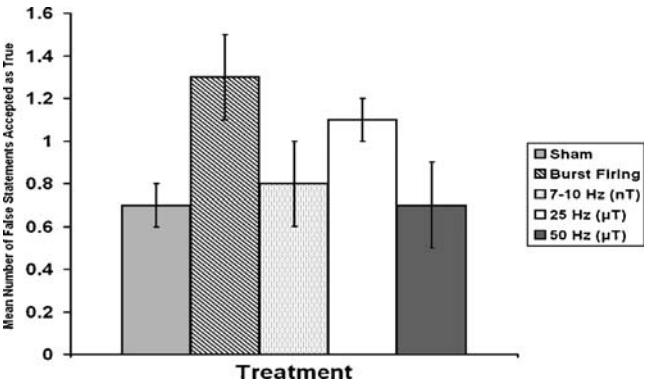

Figure 1. Mean number of false statements accepted as true for groups exposed during the refutation process of decision making to a sham condition or to either microTesla level burst-firing, 25 Hz sine-wave, or 50 Hz sine-wave patterns, or to a varying 7–10 Hz nanoTesla-level intensity magnetic fields. Vertical bars indicated standard errors of the mean.

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Post hoc analyses showed that the groups exposed to the burst-firing microT pattern accepted *on average* more false statements as true than did groups exposed to the sham field, varying 7–10 Hz nanoTesla or the 50 Hz, microT field conditions. The scores for the group exposed to the 25 Hz microT magnetic field occupied an intermediate position. The maximum between group effect size was quite small, between 10 and 15%.

Within subject effect sizes for each group separately for the responses to the different patterns of magnetic fields were larger. The values for the correlated *t*-tests (dfs = 9, with omega-squared estimates of explained variance) indicated that the numbers of false statements accepted as true when the field was present was significantly greater when the specific field was on compared to the field off for the same subjects exposed to the 25 Hz ($t = 3.00$, $p < 0.01$; 38% explained) and burst-firing fields ($t = 2.33$, $p < 0.05$; 30%) and the 7–10 Hz field ($t = 3.30$, $p < 0.01$; 50%) but not for those exposed to the sham field ($t = 1.41$, n.s; 15%) or to the 50 Hz ($t = 0.82$, n.s; 7%) conditions.

There were no statistically significant differences between treatment groups for the number of false statements accepted as true for statements with which the fields had not been presented (average mean = 0.5, average S.E.M = 0.2), true statements that were accepted as false when the fields were presented (average mean = 0.7, average S.E.M. = 0.2) or not presented (average mean = 0.6, average S.E.M. = 0.2). Except for the effects indicated in the last paragraph, there were also no statistically significant within subject differences for the different groups for the four combinations of statements.

Discussion

These results suggest that the normal refutation process when false statements are being heard or read can be disrupted by the appropriately pulsed magnetic field applied over the region of the brain (left prefrontal region) typically associated with decision making and judgement. Within a few decasec, some false statements would then be more likely to be recalled as true.

The most powerful between group effects involved the magnetic field pattern (burst-firing) that affects emotional behavior (Richards et al., 1993) and analgesia (Martin et al., 2004a,b). This group accepted twice the number of false statements as true compared to the sham group. The burst-firing pattern produced analgesic effects similar in magnitude to another frequency-modulated pulse reported by Thomas et al. (1997). Although the burst-firing field has been associated with enhanced analgesic effects following 30 min whole body exposures, we suggest that analgesic mechanisms were not likely to have been responsible for the propensity in this study to accept a false statement as true.

Instead, the frequency modulation or irregular pattern of the burst-firing field, rather than the more symmetrical shapes, may be the critical parameter. The duration of some of the components of the burst-firing field were within the range of the rapid configurational changes in cerebral electromagnetic fields associated with distinct microstates. If, as suggested by Koenig et al. (2002) that electroencephalographic activity is a consecutive string of repeating short-lasting classes of brain electric states, then appropriately patterned pulses may disrupt the serial processing. This transient effect might be the physiological bases to Spinoza's "disruption of the refutation process".

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The intensity and duration of the "pulse" applied over the left prefrontal region would be within the range that could be generated by electronic equipment during conversations using conventional telephone apparatus, especially when the receiver is held over the left ear. We have also measured very complicated patterns of intense magnetic fields generated from the internal circuitry of cell phones (not the GHz carrier fields) while the person is engaging in conversation. These patterns can often be discerned audibly if the person is standing near an operating radio tuned to the optimal station. The power-frequency (extremely low-frequency) magnetic field component adjacent to the ear from some cell phones can range between 1–10 microTesla.

It may be relevant that the largest within subject effect for accepting false statements as true occurred for the group that received the *weak* (10 nT) 7–10 Hz field continuously during the experiment. These results were surprising to us and suggest that continuous exposure to very weak frequency-modulated or phase-modulated fields within this band—that is also within the range of the Schumann resonance (Cherry, 2002) and related natural sources—might affect the refutation process in some instances. A more complicated pattern within this frequency range and with a similar intensity, originating from a southern direction and measurable at several sites on the university campus, was recorded for over an hour at 20:00 hr (local time) on February 5, 2004. This observation emphasizes the importance of continuous monitoring and measurement to detect potential transients that may have significant impact upon large populations.

The intensities, between 10 and 100 nT, of that signal were remarkably high for a natural origin. The actual origin was never identified and was never detected again during the subsequent year. However, even weaker complex magnetic fields have been shown to affect behavior (Sandyk, 1995). Appropriately patterned field strengths involving phase-modulated and frequency-modulated fields within the picoTesla have been shown to affect brain functions (Anninos et al., 1991) while changes of only a few nanoTeslsa have facilitated electroencephalographic entrainment (Subrahmanyan et al., 1985).

Although reviews by Cook et al. (2002, 2006) and Carrubba and Marino (2008) suggested the role of environmental-strength extremely low-frequency magnetic fields upon brain activity are either complicated manifestations or inconclusive, we emphasize that transient presentations by weak, appropriately patterned magnetic fields upon large populations could affect group decisions. Synergisms (Whissell and Persinger, 2007) between routinely consumed pharmacology compounds and weak, temporally complex extremely low frequency magnetic fields generated as subtractions and beats from the mixture of myriad higher frequency fields employed in modern wireless communications could markedly lower the threshold for cognitive effects.

The degree to which such patterns applied continuously or as discrete pulses can add affective salience or emotional conviction to a false statement accepted as true within the normal habitat must still be assessed. Gailey (1999) argued that only a 1 microV induced membrane potential can be detected after 10 ms by an ensemble of about 10^8 ion channels. This potential gradient is clearly within the range that could be induced by a 1–10 microT field changing every 10^{-3} to 10^{-2} s over an area of 10^{-2} m^2 for 1 s. Given the approximately 10^6 channels per neuron, then bout 100 neurons functionally coupled would be required to detect this change. In light of the recent experimental demonstration in rats that the activity of only one neuron within a cortical array can determine the occurrence of an overt response (Houweling and Brecht, 2008; Huber et al., 2008), small EM-related effects may be more important than anticipated.

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We applied the patterns over the left frontal region because maintenance of the complex integrity of the prefrontal lobes of the human brain is essential for moral judgement and moral emotion. The medial frontal and frontopolar cortices are consistently activated when moral conditions are considered relative to factual ones (Moll et al., 2003). Disruption of or damage to the ventromedial prefrontal cortices interferes with the emotional signals that are necessary for guiding decisions in the advantageous direction (Bechara et al., 1999). From this context the capacity for brief, strategically patterned weak magnetic fields to affect such complex neuro-cognitive functions may have significant social significance.

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